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علاقة نظم تربية أغنام العواس في السهوب العربية مع غاز النتروس المنبعث من التربة

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الملخص:

تعد تربية الأغنام مصدر الدخل الرئيسي للفلاحين في المناطق الجافة، ولكن زيادة انتاج الاغنام يمكن ان يؤدي الى زيادة الغازات الدفيئة المضرة بالبيئة. إن الهدف من هذه الدراسة هو تقدير نسبة غاز أكسيد النتروس (N_2O) المنبعث من المراعي في السهوب ومن انتاج الأعلاف المستخدمة في تغذية أغنام العواسي في المناطق الجافة على سبيل المثال سوريا. تم استخدام الطرق المطورة من قبل اللجنة الدولية للتغيرات المناخية (IPCC) في تقدير الانبعاثات من غاز أكسيد النتروس. تم زيارة 64 مزرعة في سوريا في سبيل الحصول على البيانات للقيام بتحليلها. تم استخدام نسبة الهطول المطري بالإضافة للغلة السنوية للمحاصيل من 2001 حتى 2009 في الحسابات والنمذجة. اظهرت النتائج أن نظم تربية الأغنام، نسبة الهطول المطري، السنة والمنطقة لها تأثيرات هامه ($p < 0.05$) على انبعاثات غاز أكسيد النتروس. قُدرت انبعاثات غاز النتروس من الاراضي في الحالات الواسعة، شبه المكثفة والمكثفة بحوالي 0.30 ± 0.093، 0.598 ± 0.113 و 2.243 ± 0.187 كغ خروف$^{-1}$ سنة$^{-1}$ على التوالي. ازدات غلة المحاصيل السنوية في مناطق الهطول العالية الأمر الذي ساعد على التقليل من انبعاثات غاز أكسيد النتروس. يساعد استخدام بقايا محصول القمح والقطن بالإضافة للصويا كعلف للأغنام على حماية السهوب من الرعي الجائر والتقليل من انبعاثات غاز النتروس. يتم تقليل إنبعاثات غاز النتروس من خلال تغيير نظام تربية الأغنام و زيادة غلة المحاصيل العلفية بإستخدام الري الاصطناعي في المناطق الجافة.

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ORIGINAL ARTICLE

Awassi sheep keeping in the Arabic steppe in relation to nitrous oxide emission from soil

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Syria

Abstract Sheep husbandry is the main source of income for farmers in arid zones. Increasing sheep production on steppes may increase the greenhouse gas production. The objective of this study was to investigate the nitrous oxide (N_2O) emissions from the steppes for Awassi sheep keeping and feed cropping in arid zones such as Syria. The methodology developed by the Intergovernmental Panel on Climate Change (IPCC) was used to estimate N_2O emissions. A survey was conducted on 64 farms in Syria to gather data for analysis. Precipitation and crop yield data from 2001 to 2009 were also used for calculation and modelling. Sheep-keeping systems, precipitation, year and the region have significant effects on N_2O emissions ($p < 0.05$). Emissions of N_2O from lands with extensive, semi-intensive and intensive systems were 0.30 ± 0.093, 0.598 ± 0.113 and 2.243 ± 0.187 kg sheep^{-1}year^{-1}, respectively. Crop production was higher in regions with high precipitation levels, which helped to reduce N_2O emissions. Using more residuals of wheat, cotton and soya as feed for sheep in the keeping systems evaluated may decrease the overuse of steppe regions and N_2O emissions. Nitrous oxide emissions of N_2O from sheep-keeping areas can be reduced by changing sheep-keeping systems and increasing the crop production in arid zones through artificial irrigation.

1. Introduction

Awassi sheep are bred for harsh living environments, which are typical to arid zones such as Syria (Hijazi et al., 2013). Sheep production is an important pillar of the Syrian agricultural sector and contributes approximately 30% of the total value of national agricultural production (ACSAD, 2005). Awassi sheep provide approximately 75% of the meat and 25% of the milk consumed in Syria (ACSAD, 2005). The number of sheep kept in Syria was 15.5 million in 2010 (MAAR, 2011). The rising demand for Awassi products means that increasing numbers of sheep will be bred,

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thus leading to an overuse of the steppe. For instance, Niu et al. (2011) stated that the Alxa desert in China has been strongly depleted by overgrazing. Providing feed is the biggest problem for sheep keepers in Syria. There are different levels of intensity in sheep keeping. The steppe (Arabic: *Badia*) of Syria has been progressively deteriorating (Louhaichi et al., 2012). This area is only suitable for breeding sheep and camels (Kassem, 2005). Approximately 15–20% of the steppes in the Middle East are already marred, and it is difficult to regenerate them because of the ever-increasing number of animals along with the ploughing of the plains without artificial irrigation (Kassem, 2005). At the same time, it is, and will continue to be, difficult to obtain enough fodder for all the sheep. In Mongolia, more than 12 million livestock died in the drought years of 1999–2002, 12,000 herder households lost all their animals, and thousands of households sank below the poverty level (Marin, 2010). A new agricultural land is required to produce more feed for the sheep. Nitrogen (N) fertiliser and manure are expected to be added to the land to obtain a good yield. Human activities, including the over-application of fertilisers, especially those containing N, and ill-managed animal farming systems, have caused a major increase in N_2O emissions (Stehfest and Bouwman, 2006; Di and Cameron, 2000). Globally, livestock production is the largest user of agricultural land. There are environmental implications associated with the expansion of livestock production (FAO, 2012). Agricultural systems, especially livestock systems, are a large source of greenhouse gas (GHG) emissions and reactive nitrogen (e.g., NH_3, NO_x; Drouet et al., 2011). Nitrous oxide global-warming potential (GWP) is 298 times the GWP of carbon dioxide (CO_2; IPCC, 2006). Furthermore, N_2O is an important atmospheric constituent because it is a long–living GHG that is also the major source of stratospheric nitric oxide (NO; Mosier et al., 1996). Natural sources of N_2O are soils and oceans. The anthropogenic increase is primarily caused by accelerated soil emissions through the application of N fertilisers and animal manure in agriculture (Stehfest and Bouwman, 2006). Nitrous oxide is released during microbial transformations of N, for example by nitrification, the oxidation of ammonium (NH_4^+) to nitrate (NO_3^-), and by denitrification, that is the reduction of NO_3^- to N_2 (Yan et al., 2003). Corn requires much more N fertiliser than other crops (Kraatz et al., 2009). However, less than half of the total N input via fertilisers and animal manure in crop production is effectively utilised, while the remainder is dissipated into the adjacent environment, where it contributes to a range of negative ecological and human health effects (Erisman et al., 2007; Oenema et al., 2009). The aforementioned literature shows that GHGs, such as N_2O, are important to consider in arid zones such as Syria. Various equations have been established, such as those by Bouwman et al. (2002) and the IPCC (2006), to estimate direct N_2O emissions from the soil. Both of these methodologies depend on the N input of the fertiliser to estimate N_2O emissions from the soil. In this study, the state of keeping systems, the use of the steppe and feed cropping will be analysed using data from Syria. The objective of this research is to calculate the N_2O emissions from the land used for feed cropping and to compare the emission levels among different sheep-keeping systems to determine the best management practices for sheep keeping and food cropping.

2. Materials and methods

2.1. Site description

This study was conducted at various farms across Syria (Fig. 1). The Syrian Ministry for Agriculture and Agrarian Reform (MAAR) divided Syria into five settlement zones according to agricultural activities and the amount of annual precipitation. The sizes of the five areas, along with their respective amounts of precipitation, are as follows: (1) 27,036 km^2 (14.6%): 350 mm $year^{-1}$ (2) 24,628 km^2 (13.3%): 250–350 mm $year^{-1}$, (3) 13,147 km^2 (7.1%): 250 mm $year^{-1}$, (4) 18,332 km^2 (9.9%): 200–250 mm $year^{-1}$ and (5) 102,034 km^2 (55.1%): 100–150 mm $year^{-1}$ (MAAR, 2009) (Fig. 1). Settlement zone 5 is defined as the Steppe, which is located in the eastern part of Syria, represents 55% of the national territory and is the main region for sheep production. Zones 1 and 2 are wheat production areas, whereas barley is the dominant crop in zones 3 and 4 (Shomo et al., 2010). A total of 64 farms with different SKSs were surveyed in various Syrian governorates, and they are each marked with a sheep in (Fig. 1) These farms were located within the governorates of Aleppo and Idleb in the north; Damascus, Sweida, Daraa and Quneitra in the south; Al-Raqqa, Hasakeh and Dair Ezzor in the east; and Homs and Hama in the west.

2.2. Data collection

Data were collected from September to November of 2009. At this time of the year, the summer is at its end, and the temperature is acceptable for moving between the farms. The best way to gather the data was to prepare a custom questionnaire that collected data on sheep production (including the number of animals, their body mass, milk yield per day and wool yield) and general information about the keeping-system and farm location, including yearly feed rations on each farm, the period of pasturing on natural pastures, the duration of pasturing on agricultural residuals, the keeping period in stables and the amount and use of excrements. In total, 64 farms with different keeping systems were visited in various regions of Syria. Data on feed production were gathered from the Ministry of Agriculture in Syria (MAAR), from the International Centre for Agricultural Research in Dry Areas (ICARDA) and the Arabic Centre for Studies of Arid Zones and Dry Lands (ACSAD) The feed sources during the year were the natural steppe and residuals from feed cropping, such as wheat and cotton, and concentrate feed, which is mixed differently according to the particular situation on each farm. The harvest products consisted of the following grains: barley, wheat, wheat shells, soya, corn and cotton seed cake. Additionally, farms bought concentrate feed from the Syrian Public Institution for Feed. Data on precipitation were gathered from MAAR from 2001 to 2009.

2.3. Sheep-keeping systems

The sheep-keeping systems differ according to the keeping period in stables, type of stables and yearly feed of sheep.

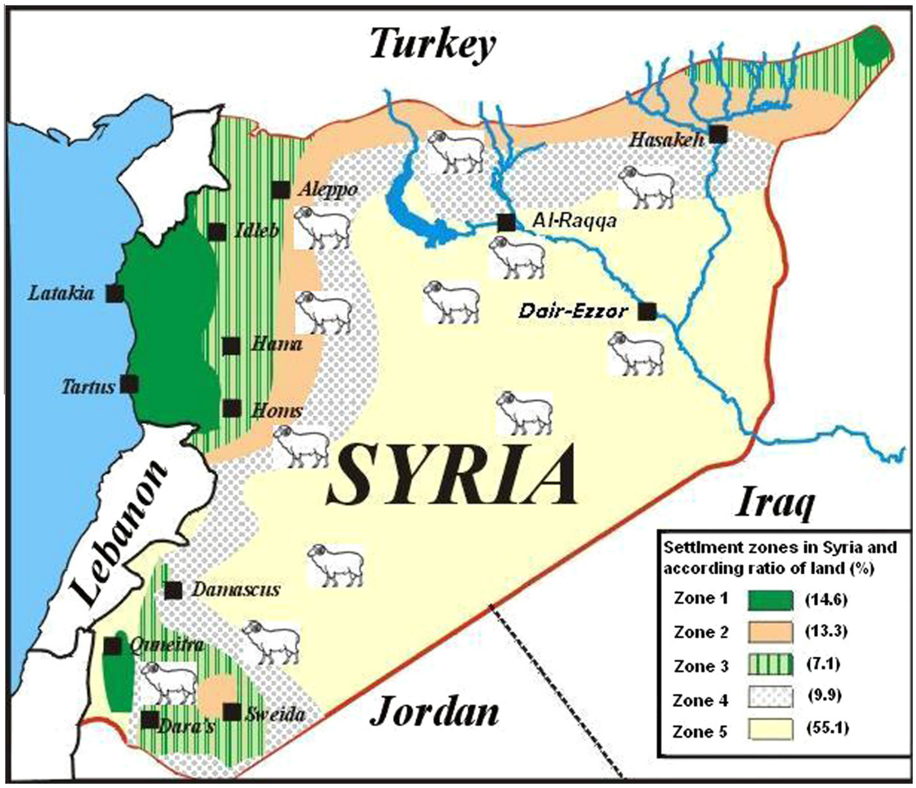

Figure 1 Map of Syria with settlement zones and marked regions (sheep) where farm data were collected (modified after MAAR, 2009).

Depending on the aforementioned differences, the keeping-systems could be categorised into three groups: extensive, semi-intensive and intensive.

2.3.1. The extensive system

The extensive keeping system relies heavily on range grazing through migratory movement on the steppe. It is considered the most common form of sheep keeping in Syria and has been used by Bedouins for ages. There is no closed stable except a tent installed in a place near grass. Sheep feed for 4–9 months on the steppe on various agricultural residuals, which could be 1 month on cotton residual, 1–4 months on wheat residual, or 2–5 months on concentrate feed. Between 17% and 45% of the feed used per year is concentrate feed. Bedouins roam the steppe looking for grass. They take part in a pasture circulatory system, in which the herds are brought at regular intervals from the east to the west and the other way around. After the first rains on the steppe, a young, fresh pasture grows, and the herds are then taken to the east. At the end of the spring, when the steppes are grazed, the sheep are brought back to the west to pasture on the harvested cropland (wheat and cotton residual).

2.3.2. The intensive system

In this system, sheep are kept in closed cement stables and provided with concentrate feed for more than 10 months of the year. Therefore, more than 85% of the yearly feed used is concentrate feed. These systems are found in semi-urban areas or areas near main urban centres. In this study, two farms were visited that used this keeping system. Both of the farms were research centres associated with the ACSAD and Damascus University.

2.3.3. The semi-intensive system

The semi-intensive keeping system also relies on range grazing, but in this case, farmers have settled down. They use a combination of grazing on rangeland near their settlement and concentrate feed. Sheep are kept in closed cement stables and feed 4–10 months on the steppe, 1–4 months on wheat residuals, and 2–7 months on concentrate feed. Between 17% and 60% of the feed per year is concentrate feed.

2.4. Estimation of N_2O emissions

In this study, the IPCC methodology has been used to calculate the amount of N_2O emissions, which are induced by the addition of N fertilisers, from the soil dedicated to feed cropping. The IPCC methodology to estimate the emissions is described in the following Eq. (1) (IPCC, 2006):

$$E_{N_2O} = m_N \times EF_{N_2O} \times \gamma N_2O \quad (1)$$

where E_{N2O} is the flux of N_2O directly emitted from soils (kg year^{-1}), m_N is the amount of N that is used for fertilisation (kg year^{-1}), EF_{N2O} is the emissions factor for N_2O (kg N_2O kg^{-1}N^{-1}) and γN_2O is a mass conversion factor ($\gamma N_2O = 44/28$).

In this study 'Tier 1' was used, and a fixed emission factor was used for the entire country, '$EF_{N2O} = 0.0125$ kg N_2O kg^{-1}N^{-1}'. To estimate the N_2O emissions from the steppe, N_2O emissions from grazing sheep excrement and urine were considered as the only sources of N_2O in the steppe. The body mass and the period of keeping sheep on the steppe for each farm were determined by using the data gathered from the customised questionnaire. Nitrogen in excrement was calculated according to the Eqs. (2) and (3) by Moussa and Hasnna (2000):

$$\text{Mass } E = C_{EF} \times \text{Mass } F \quad (2)$$

where Mass E is excrement mass (kg day^{-1}), Mass F is feed mass (kg day^{-1}) (=2% of body mass) and C_{EF} is a conversion factor (0.25), and

$$N_{EX} = C_N \times \text{Mass}E \quad (3)$$

where N_{EX} is the amount of N in excrement (kg day^{-1}), Mass E is excrement mass (kg day^{-1}) and C_N is a conversion factor (0.75%). The nitrogen from urine per sheep is 0.015 kg day^{-1} (Moussa and Hasnna, 2000). According to ACSAD (2007), the mean quantity of feed in steppe pastures is 300 kg ha^{-1}year^{-1}. The number of sheep per hectare was calculated for each farm according to body mass, feed mass and the mean quantity of feed in one hectare. Emissions of N_2O from dedicated soils on the steppe caused by the N in excrement and urine of grazing sheep were calculated using Eq. (1). The amount of N fertiliser was based on calculations from MAAR (2009) (Table 1).

The estimation of the N_2O emissions from wheat residual and wheat shells was adapted from the wheat yield, which included grain and wheat shells. The grain part of the wheat and the wheat shells accounted for 86% and 14% of the yield, respectively (MAAR, 2009). Therefore, wheat was used as wheat shells in rations and as wheat residual on fields. According to Dieb (1999), the emission flux of N_2O directly emitted from soils by producing wheat straw was considered as described in the following Eq. (4):

$$E_S = C_W \times E_y \quad (4)$$

where E_S is the flux of N_2O directly emitted from soils by producing wheat straw, E_y is the emission flux of N_2O directly emitted from soils by producing wheat yield and C_W is a conversion factor $\left(\frac{0.33}{2.08}\right)$ equivalent to the distribution of N in the plant.

The term E_y has been calculated using Eq. (1).

Emissions of N_2O originating from the production of cotton residual and cotton seed cake that were used for feeding the sheep were also calculated using Eq. (1) accordingly. Masri (2001) reported that 50% of cotton was grown for pasturing as cotton residual. Of the cotton grown, 4.5% was processed for producing cotton seed cake (MAAR, 2009). Therefore, one hectare of cotton cropland was fertilised with 80 kg ha^{-1}year^{-1} in the form of N-mineral fertiliser and 30 t ha^{-1}year^{-1} in the form of manure (MAAR, 2009).

2.5. Statistical analysis

For the calculations, precipitation and the crop yields have been used for the period 2001–2009, which was given in the MAAR yearly report. Farm data were gathered in 2009 using the questionnaire. The farm data have been used for all the years from 2001 to 2009 with the assumption that the farms and their properties did not change.

A statistical analysis was carried out to evaluate the influence of the following factors on N_2O emissions per sheep: keeping systems, precipitation, region and year. Therefore, a linear mixed model was applied using the mixed procedure. Main factor combinations were tested. This model [Eq. (5)] was developed for the results gathered from all 64 farms at a significance level of $\alpha = 0.05$.

$$E_{ijmk} = \mu_N = a_i + b_j + c_m + f_k + rx + wy + e_{ijmk} \quad (5)$$

where E_{ijmk} represents the calculated emissions of N_2O, μ_N signifies the general mean of N_2O emissions and the terms keeping-system (a_i), year (b_j) and region (c_m) account for fixed effects. Furthermore, the random farm effect is expressed by f_k; the covariable estimate for precipitation is r (x = mm year^{-1}); the body mass of sheep (y = kg) is given by the covariable estimate w, and e_{jimk} represents the random residual. All data were analysed using statistical software package SAS v.9.2 (SAS, 2010). Adjustment for multiple comparisons of means of levels within a fixed effect was made using the "simulate" option to adhere to the global significance level of $\alpha = 0.05$.

3. Results and discussion

3.1. Statistical model

The investigated farms consisted of 46 extensive, 16 semi-intensive and two intensive keeping systems.

Only one farm was visited in Daraa and in Hama. The average sheep body masses at these farms were 60 kg and 66 kg, respectively, and they are clearly higher than at other regions, such as Aleppo 47 ± 1.30 kg (with the including of a standard deviation) (Table 2). The number of the sheep ranged from 40 to 1000 per farm. Owing to the varying numbers of sheep, it was difficult to estimate characteristics of the sheep flock in Syria. The proportional composition of the feed varied throughout the year in different regions of Syria (Table 3).

Table 1 The amount of N in mineral fertilisers and in manure used for feed cropping.

Concentrate feed	N in mineral fertiliser*	Manure	N in Manure**	Yield***
	kg ha^{-1}year^{-1}	t ha^{-1}year^{-1}	kg ha^{-1}year^{-1}	kg ha^{-1}year^{-1}
Barley	30	15	112.5	655
Wheat	60	20	150	2575
Corn	100	40	300	3955
Soya	20	5	37.5	1614

* N content equates 46% according to MAAR in 2009.
** According to Eq. (3).
*** Mean yield for all of Syria.

Table 2 Overview of the average ± standard deviation of number of sheep, body mass of sheep, annual precipitation and barley yield.

Regions	Number* of farms	Number* of sheep	Body mass* kg	Mean of** precipitation mm $year^{-1}$	Mean of barley** yield kg ha^{-1}
Damascus	10	170 ± 147	52 ± 7.5	184 ± 19	503 ± 328
Homs	10	249 ± 177	49 ± 4.91	466 ± 133	461 ± 265
Sweida	4	126 ± 92	46 ± 8.54	305 ± 93	351 ± 310
Quneitra	3	313 ± 83	58 ± 2.89	563 ± 37	1,393 ± 342
Dair-Ezzor	10	257 ± 343	47 ± 5.03	146 ± 51	392 ± 496
Hassake	14	188 ± 125	53 ± 9.11	223 ± 67	587 ± 508
Al-Raqqa	3	570 ± 125	48 ± 7.64	157 ± 52	400 ± 325
Aleppo	5	520 ± 446	47 ± 1.30	440 ± 47	941 ± 493
Idleb	3	40 ± 168	49 ± 4.04	515 ± 91	1,673 ± 693
Daraa	1	210 ± 0	60 ± 0	244 ± 84	543 ± 440
Hama	1	1000 ± 0	66 ± 0	354 ± 88	1,016 ± 627

* Data collected from the questionnaire.
** Data collected from the literature (2001–2009).

All statistical analyses of the model based on Eq. (5) showed different influences on N2O emissions when applying a test of fixed effects (Table 4).

Keeping system, precipitation, year and region had significant effects on N_2O emissions ($p < 0.0001$), while body mass had no significant effects on N_2O emissions ($p = 0.41$). Furthermore, there were no significant differences between the extensive and semi-intensive keeping systems ($p = 0.241$).

Table 4 Test of fixed effects from the analysis of variance.

Effect	Num DF*	Den DF**	F Value	Pr > *F*
Keeping-system	2	61.7	49.42	< .0001
Year	8	498	31.99	< .0001
Region	10	46.3	4.87	< .0001
Precipitation	1	498	34.60	< .0001
Body mass	1	40.7	0.69	0.4102

* Num DF: Numerator degree of freedom.
** Den DF: Denominator degree of freedom.

3.2. Keeping system and feed effects

Sheep in both extensive and semi-intensive systems depend on grazing on the natural steppe. On average, sheep in extensive and semi-intensive keeping systems grazed on the natural steppe approximately 151 ± 60 day $year^{-1}$ and 208 ± 71 day $year^{-1}$, respectively. Using steppe is 14% lower in the extensive keeping system than in the semi-intensive keeping system. In extensive keeping, sheep grazed on residuals of wheat and cotton approximately 92 ± 14 day $year^{-1}$ and 19 ± 14 day $year^{-1}$, respectively. In the semi-intensive keeping system, sheep grazed on wheat residuals only 38 ± 57 day $year^{-1}$.

The yields of barley, corn and soya were 655, 3955 and 1614 kg, respectively (Table 3). This result implies that one kg of barley, corn and soya produced N_2O emissions of 38×10^{-4}, 13×10^{-4} and 6×10^{-4} kg $ha^{-1}year^{-1}$, respectively. Wheat shells and cotton cake produced N_2O emissions of 1×10^{-4} and 0.58×10^{-4} kg $ha^{-1}year^{-1}$, respectively. On average, the steppe produced N_2O emissions of 0.2×10^{-4} kg $ha^{-1}year^{-1}$. Residuals of wheat and cotton produced N_2O emissions of 1×10^{-4} and 6×10^{-4} kg $ha^{-1}year^{-1}$, respectively. Keeping systems have different properties. As outlined in the aforementioned description, each system used different feed composition and produced different N_2O emissions.

The extensive system used lower concentrate feed than the other two systems; 27% of the yearly feed contracture is concentrate feed (Table 5). In the extensive keeping system, the N_2O emissions varied from 0.056 kg $sheep^{-1}year^{-1}$ to 5.842 kg $sheep^{-1}year^{-1}$. In contrast, the semi-intensive keeping

Table 3 Feed compositions and their time of consumption in different regions of Syria.

Region	Geographic location in Syria	Concentrate feed	Natural pastures	Cotton residual	Wheat residual
		Months	Months	Months	Months
Damascus	South	5	7	–	–
Daraa	South	12	–	–	–
Sweida	South	3	9	–	–
Quneitra	South	3	4	1	4
Dair-Ezzor	East	4	4	–	4
Hassake	East	3	4	1	4
Al-Raqqa	East	4	4	1	3
Aleppo	North	3	4	1	4
Idleb	North	4	4	–	4
Homs	West	4	6	–	2
Hama	West	2	6	–	4

Table 5 Feed compositions used in keeping-systems and corresponding least square means of N_2O emissions.

Keeping-system	Concentrate feed	Steppe	Cotton residual	Wheat residual	Least square means of N_2O emissions
	(%)	(%)	(%)	(%)	kg sheep^{-1} year^{-1}
Extensive	27	43	5	25	0.301 ± 0.093
Semi-intensive	34	57	–	9	0.598 ± 0.113
Intensive	100	–	–	–	2.243 ± 0.187

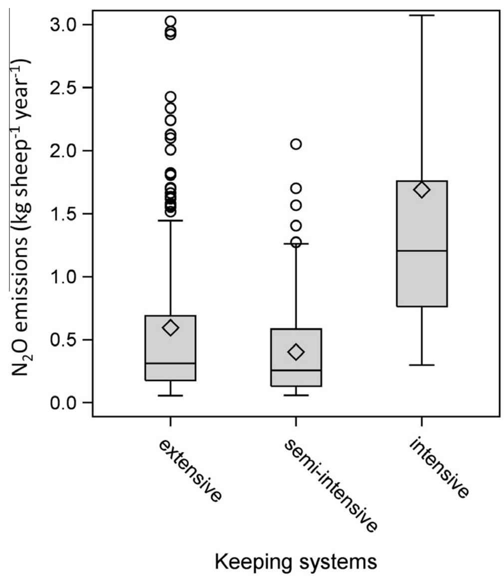

Figure 2 Box-and-whisker plot* of N_2O emissions within the different sheep keeping system. *Definition of box-and-whisker plot: (bottom: 25th percentile; top: 75th percentile; middle: 50th percentile; diamond: mean value).

system ranged from emissions of 0.057 kg sheep^{-1}year^{-1} to 2.052 kg sheep^{-1}year^{-1}. Within the intensive keeping system, N_2O emissions ranged from 0.299 kg sheep^{-1}year^{-1} to 5.272 kg sheep^{-1}year^{-1} (Fig. 2).

The use of the extensive keeping system produced lower N_2O emissions of 1.942 ± 0.249 kg sheep^{-1}year^{-1} than the intensive keeping system. Using the semi-intensive keeping system resulted in lower N_2O emissions (1.645 ± 0.167 kg sheep^{-1} year^{-1}) than the intensive option.

The semi-intensive system increased N_2O emissions compared with the extensive keeping system. This finding can be explained by the semi-intensive keeping system using concentrated feed more frequently than the extensive keeping system, at 114 ± 47 day year^{-1} and 98 ± 17 day year^{-1}, respectively. This finding is consistent with results of Oenema et al. (1997) and Stehfest and Bouwman (2006), who found that the N-application rate has a significant influence on direct N_2O emissions. Comparing the emission flux of N_2O directly emitted from soils grown with cropping feed, such as barley, corn and soya, with the N-application rate, listed in Table 1, we find that the amount of N in applied mineral fertilisers and manure increased N_2O emissions. Reducing the N-application rate can be regarded as an accessible strategy for mitigating N_2O emissions. Any reduction of an N-application must ensure the crop productivity. However, applying more soya and corn than barley in the concentrate feed reduced N_2O emissions. Importing concentrate from outside is difficult because of high costs. Therefore, improving the using of crop residuals, such as wheat shells and cotton cake, would help to reduce N_2O emissions. At the same time, integrating locally available, nonconventional feedstuffs, such as wheat straw and cotton seed cake, into balanced dairy sheep diets can decrease feed costs to resource-poor farmers while enhancing total yields of milk and milk constituents without compromising milk-quality components (Hilali et al., 2011). An extensive keeping system is the form most used in all the regions of Syria, especially where the natural steppe could not be used for agricultural activity. The use of concentrate feed in the semi-intensive keeping system was 7% higher compared to the extensive keeping system (Table 5). Excrement and urine from grazing sheep present major sources of N_2O emission in the natural steppe. Velthof and Oenema (1995) found that grazing generally increases N_2O emissions from grasslands because of additional N inputs. The extensive keeping system created lower N_2O emissions than the semi-intensive and intensive keeping systems (Table 5). This result can be explained by the low percentage of concentrate feed and higher percentage of crops residuals (wheat and cotton) (Table 5). Emissions of N_2O depend on the quantity and type of feed used, as stated by Muylaert et al. (2007). The semi-intensive keeping system used more natural pastures than the extensive system, which caused overuse of the steppe. Alternative use of residuals of wheat, cotton and soya as feed will help to improve sheep management practices in the extensive and semi-intensive keeping systems. These alternative uses will also prevent the overuse of the steppe and decrease N_2O emissions. There were no significant differences in N_2O emissions between the extensive and semi-intensive keeping systems. This finding points to the fact that extensive and semi-intensive keeping systems should be aimed at protecting the steppe and reducing grazing on natural pasture. The semi-intensive keeping system generated lower N_2O emissions compared to the intensive option (Table 5). This outcome can be explained by the large percentage of natural pasture and crop residual used in the semi-intensive keeping system; this feed source pattern can therefore be regarded as a feasible N_2O emission abatement strategy. The Bedouins belong to a long tradition that is cognizant of weather conditions and the crucial role of feed for survival during dry years, both for themselves and for their sheep. Any suggested changes to sheep management should be made easily possible for the Bedouins.

3.3. Year and rainfall

For the survey data collected, all 64 farms represented different N_2O emissions per sheep and year. The year 2008 differed significantly ($p < 0.0001$) from all the other years (2001–2009) and had the highest N_2O emissions compared with the other years (Table 6).

Table 6 The significant differences between the years for least squares means (LSM) of N_2O emissions according to Eq. (5).

Year vs	Year	Estimate** kg sheep^{-1}year^{-1}	Standard error	DF*	t-value	Adj P
2001	2008	−0.9559	0.08832	498	−10.82	< .0001
2002	2004	−0.3437	0.08384	498	−4.10	0.001
2002	2008	−1.1495	0.08552	498	−13.44	< .0001
2002	2009	−0.3604	0.08322	498	−4.33	0.0003
2003	2008	−0.9016	0.09673	498	−9.32	< .0001
2004	2006	0.3338	0.08387	498	3.98	0.0021
2004	2007	0.2658	0.08400	498	3.16	0.0443
2004	2008	−0.8058	0.08734	498	−9.23	< .0001
2005	2008	−0.8579	0.08577	498	−10.0	< .0001
2006	2008	−1.1396	0.08549	498	−13.33	< .0001
2006	2009	−0.3505	0.08321	498	−4.21	0.0004
2007	2008	−0.2825	0.08317	498	−12.55	< .0001
2008	2009	0.7891	0.08518	498	9.26	< .0001

* DF: degree of freedom.
** Estimate is the mean N_2O emissions per sheep according to Eq. (5).

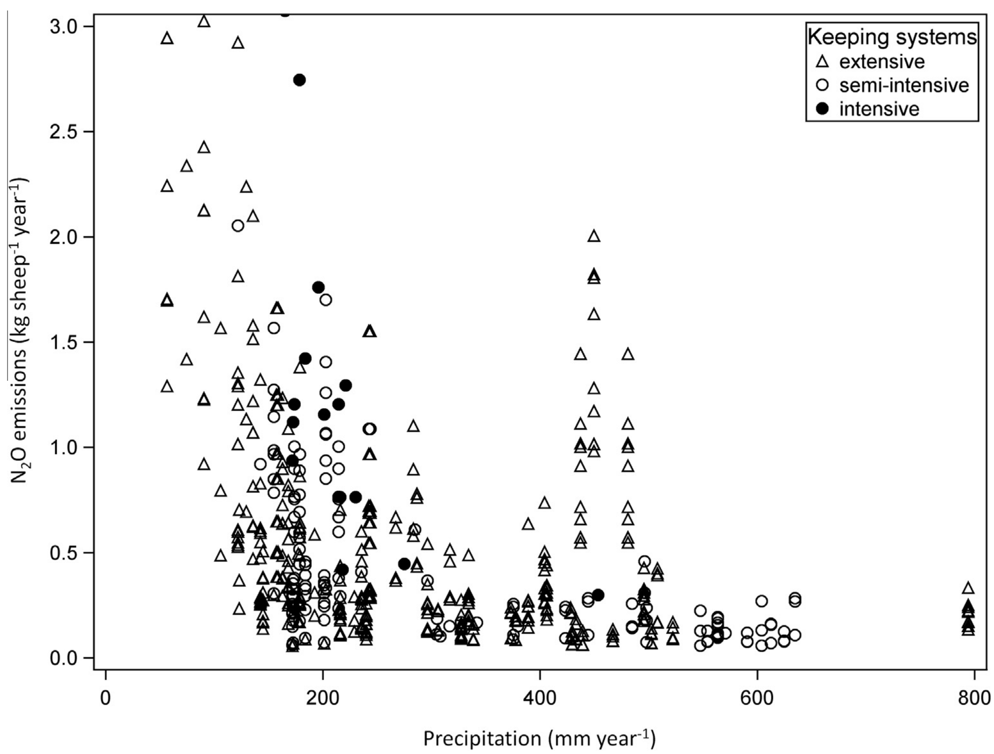

Figure 3 Scatter plot of N_2O emissions from 64 farms vs. occurring precipitation (2001–2009).

The model from Eq. (5) indicates that 1 mm of precipitation reduces N_2O emissions by 0.00196 ± 0.000334 kg sheep^{-1} year^{-1}. In the extensive keeping system, emissions of N_2O increased when precipitation was less than 100 mm year^{-1} (Fig. 3).

The different levels of precipitation during the years 2001 to 2009 had significant effects on N_2O emissions (Table 6). The relationship between precipitation and N_2O emissions showed negative values in particular regions. The growth of grass and the cereal yield in the steppe highly depend on precipitation. Low precipitation negatively affects the steppe and its yield. Regarding the extensive keeping system, N_2O emissions rose, especially when precipitation was less than 56 mm year^{-1}. This finding can be explained by the direct relationship between the yield and precipitation; yield increases when precipitation increases (assuming the fertilisers are of the same quality), and the effect of precipitation on N_2O emissions was considered indirect according to the relationship between yield and precipitation. A comparison of the years from 2001 to 2009 shows that precipitation in 2008 was the lowest all over Syria, and as a result, N_2O emissions were highest in 2008 (Table 6). The clear decrease in precipitation each year represents a serious problem for Syria. The farmers plant and fertilise, hoping that an adequate amount of rain will produce a good yield. Barley is the most important crop for feeding sheep; it is almost never

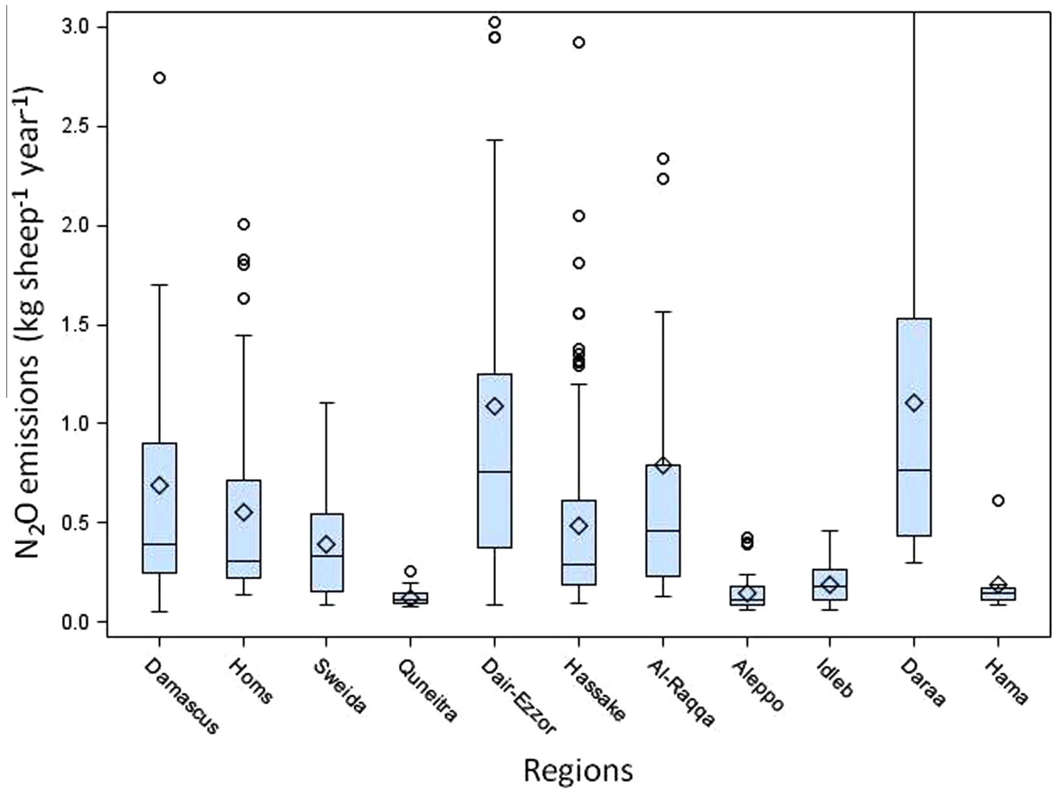

Figure 4 Box-and-whisker plot* of N_2O emissions within the different regions. *Definition of box-and-whisker plot: (bottom: 25th percentile; top: 75th percentile; middle: 50th percentile; diamond: mean value).

Table 7 Selected differences between the regions for least squares means (LSM) of N_2O emissions according to Eq. (5).

Region vs	Region	Estimate kg sheep^{-1}yr^{-1}	Standard error	DF	*t*-value	Pr > |t|	Adj *P*
Dair-Ezzor	Damascus	0.791	0.202	39.1	3.9	0.0004	0.014
Dair-Ezzor	Daraa	1.696	0.304	197	5.57	<.0001	0.0004
Dair-Ezzor	Hassake	0.513	0.136	43.6	3.75	0.0005	0.0213
Damascus	Daraa	0.904	0.231	513	3.91	0.0001	0.014
Damascus	Homs	−0.8728	0.2256	57.5	−3.87	0.0003	0.016
Daraa	Hassake	−1.183	0.2826	141	−4.19	<.0001	0.0083
Daraa	Homs	−1.7775	0.3123	210	−5.69	<.0001	0.0003
Daraa	Idleb	−1.2134	0.2773	227	−4.38	<.0001	0.0052
Daraa	Quneitra	−1.1906	0.276	253	−4.31	<.0001	0.006
Daraa	Sweida	−1.4423	0.3281	177	−4.4	<.0001	0.0048
Hama	Homs	−0.9749	0.2574	22.6	−3.79	0.001	0.0193
Hassake	Homs	−0.5945	0.1551	74.3	−3.83	0.0003	0.0177

artificially irrigated. Wheat is in competition with barley; it is planted in the superior areas because it is more profitable than barley. The planting of barley was displaced to second-class areas, which have very low precipitation. By planting barley in first-class areas, farmers could obtain more yield with simultaneously lower N_2O emissions per hectare. Using better irrigation systems would improve the yield and simultaneously reduce N_2O emissions.

3.4. Regions

The results show differences between the regions and between farms within one region. Dair-Ezzor and Daraa showed the greatest difference between the maximum and minimum levels of N_2O emissions, followed by Hassake, Al-Raqqa and Homs (Fig. 4).

Daraa differed significantly from Hassake, Homs, Idleb, Quneitra and Sweida (Table 7). Dair-Ezzor differed significantly from Damascus, Hassake and Daraa. According to the linear model, N_2O emissions in Dair-Ezzor and Homs were 1.566 ± 0.169 kg sheep^{-1}year^{-1} and 1.648 ± 0.174 kg sheep^{-1}year^{-1}, respectively. In these two regions, the highest means of N_2O emissions were estimated.

Overall, less precipitation was detected in the eastern parts of Syria (90–140 mm year^{-1}). This fact had a major effect on the yield of feeds such as barley. This is evident in Dair-Ezzor, which had a precipitation of 90 mm year^{-1}and a barley yield that was clearly lower than in the other regions (Table 2). It would be better to grow crops only in regions with good precipitation. In Damascus, minor agricultural activities exist, and most of the feed was bought from the Syrian Public Institution for Feed. The Dair-Ezzor region showed the greatest difference between the maximum and minimum levels of N_2O emissions, followed by Hassake, Al-Raqqa and Homs (Fig. 4). It can be assumed that the small amounts of yearly precipitation in Dair-Ezzor caused the high N_2O emissions. Moreover, the eastern part of Syria has a large region with various natural pastures, and this may have caused large differences between maximum and minimum N_2O values.

4. Conclusion

The IPCC methodology was used to calculate the N_2O emissions from sheep keeping systems, as induced by the addition of N fertilisers from the soil dedicated to feed cropping. It results from this study that the intensive keeping system produces higher N_2O emissions than the intensive and semi-extensive systems. This is due to the use of larger amounts of mineral N fertilisers in the intensive system. Feeding sheep with more soya and corn than barley would lead to less overall N_2O emissions. Decreasing the overuse of steppe could be possible by using more residuals of wheat or cotton as feed in keeping systems. The relationship between precipitation and N_2O emissions showed negative values in eastern regions such as Dair-Ezzor, Al-Raqqa and Hassake, with crop yield increasing when precipitation increases. Farmers are therefore encouraged to plant barley in areas that have more than 350 mm of precipitation per year to achieve greater yield and lower N_2O emissions. Using better irrigation systems will improve the yield and simultaneously reduce N_2O emissions in the eastern regions which have low precipitation. The findings of this study support proposing further management work to educate farmers and encourage improvements of agrarian practices in Syria and generally in arid zones.

References

ACSAD, 2005. Arab center for studies of arid zones and dry lands. Annual technical report.

ACSAD, 2007. Arab center for studies of arid zones and dry lands. Annual technical report.

Bouwman, A.F., Boumans, L.J.M., Batjes, N.H., 2002. Emissions of N2O and NO from fertilized fields: summary of available measurement data. Global Biogeochemical Cycles 16 (4): art. No. 2001GB001811.

Di, H.J., Cameron, K.C., 2000. Calculating nitrogen leaching losses and critical nitrogen application rates in dairy pasture systems using a semi-empirical model. N Z J. Agri. Res. 43, 139–147.

Dieb, M., 1999. Fertilizer and plant nutrition, second ed. Publications of the University of Damascus, Damascus, pp. 75–102, (in Arabic).

Drouet, J.L., Capian, N., Fiorelli, J.L., Blanfort, V., Capitaine, M., Duretz, S., Gabrielle, B., Martin, R., Lardy, R., Cellier, P., Soussana, J.F., 2011. Sensitivity analysis for models of greenhouse gas emissions at farm level. Case study of N_2O emissions simulated by the CERES-EGC model. Environ. Pollut. 159, 3156–3161.

Erisman, J.W., Bleeker, A., Galloway, J., Sutton, M.S., 2007. Reduced nitrogen in ecology and the environment. Environ. Pollut. 150, 140–149.

FAO, 2012. FAO Statistical yearbook. World food and agriculture. Food and Agriculture Organization of the United Nations, Rome.

Hijazi, O., Berg, W., Moussa, S., Ammon, C., Von Bobrutzki., Brunsch, R., 2013. Comparing methane emissions from different sheep-keeping systems in semiarid regions: a case study of Syria. Journal of the Saudi Society of Agricultural Sciences. http://dx.doi.org/10.1016/j.jssas.2013.01.008.

Hilali, M., Iniguez, L., Knaus, W., Schreiner, M., Rischkowsky, B., Wurzinger, M., Mayer, H.K., 2011. Prospects for using nonconventional feeds in diets for Awassi dairy sheep in Syria. J. Dairy Sci. 94, 3014–3024.

Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.). IPCC Guidelines for national greenhouse gas inventories, prepared by the national greenhouse gasinventories programm. IGES, Japan.

Kassem, R., 2005. Small ruminant breeds of Syria. In: Iniguez, L. (Ed.). In: Characterization of small ruminant breeds in west Asia and north Africa, vol. 1. ICARDA, International Centre for Agricultural Research in the dry areas, p. 183, chapter six.

Kraatz, S., Berg, W., Brunsch, R., 2009. Factors influencing energy demand in dairy farming. S. Afr. J. Anim. Sci. 39 (1), 137–140.

Louhaichi, M., Ghassali, F., Salkini, A.K., Petersen, S.L., 2012. Effect of sheep grazing on rangeland plant communities: case study of landscape depressions within Syrian arid steppes. J. Arid Environ. 79, 101–106.

MAAR, 2009. Ministry of agriculture in Syria. Yearly report.

MAAR, 2011. Ministry of agriculture in Syria. Yearly report.

Marin, A., 2010. Riders under storms: contributions of nomadic herders' observations to analyzing climate change in Mongolia. Global Environ. Change 20, 162–176.

Masri, Y., 2001. The importance of cotton seed husk and its fodder uses. In: Cotton from Cropping to Consumer. Faculty of Agriculture. Publications of the University of Aleppo, pp. 361–370 (in Arabic).

Mosier, A.R., Duxbury, J.M., Freney, J.R., Heinemeyer, O., Minami, K., 1996. Nitrous oxide emissions from agricultural fields: assessment, measurement and mitigation. Plant Soil 181, 95–108.

Moussa, S., Hasnna, J., 2000. Basics of Animal Production, first ed. Publications of the University of Damascus, Damascus, pp: 238–250, (in Arabic).

Muylaert de Araujo, M.S., Pires de Campos, C., Rosa, L.P., 2007. Historical emissions, by country, of N_2O from animal manure management and of CH_4 from enteric fermentation in domestic livestock. Climate Res. 34, 253–258.

Niu, D., Haal, S.J., Fu, H., Kang, J., Qin, Y., Elser, J.J., 2011. Grazing exclusion alters ecosystem carbon pools in Alxa desert steppe. N. Z. J. Agric. Res. 53, 127–142.

Oenema, O., Velthof, G.L., Yamulki, S., Jarvis, S.C., 1997. Nitrous oxide emissions from grazed grassland. Soil Use Manag. 13, 288–295.

Oenema, O., Witzke, H.P., Klimont, Z., Lesschen, J.P., Velthof, G.L., 2009. Integrated assessment of promising measures to decrease nitrogen losses from agriculture in EU-27. Agric. Ecosystems Environ. 133, 280–288.

SAS, 2010. SAS Statistical Analysis Software, Version 9.2, SAS Institute, Cary, NC, USA.

Shomo, F., Ahmed, M., Shideed, K., Aw-Hassan, A., Erkan, O., 2010. Sources of technical efficiency of sheep production systems in dry areas in Syria. Small Ruminant Res. 91, 160–169.

Stehfest, E., Bouwman, L., 2006. N_2O and NO emissions from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions. Nutr. Cycling Agroecosystems 74, 207–228.

Velthof, G.L., Oenema, O., 1995. Nitrous oxide fluxes from grassland in the Netherlands: II. Effects of soil type, nitrogen fertilizer application and grazing. Eur. J. Soil Sci. 46, 541–549.

Yan, X., Akimoto, H., Ohara, T., 2003. Estimation of nitrous oxide, nitric oxide and ammonia emissions from croplands in East, Southeast and South Asia. Global Change Biol. 9, 1080–1096.